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**A video analysis of head injuries satisfying the criteria for a Head Injury Assessment in professional Rugby Union: A prospective cohort study**

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*Abstract*

**Objectives**: Concussion is the most common match injury in professional Rugby Union, accounting for 25% of match injuries. The primary prevention of head injuries requires that the injury mechanism be known so that interventions can be targeted to specifically overall incidence by focusing on characteristics with the greatest propensity to cause a head injury.
**Methods**: 611 Head Injury Assessment (HIA) events in professional Rugby Union over a three- year period were analysed, with specific reference to match events, position, time and nature of head contact
**Results**: 464 (76%) of HIA events occur during tackles, with the tackler experiencing a significantly greater propensity for an HIA than the ball carrier (1.40 HIAs/1000 tackles for the tackler vs 0.54 HIAs/1000 tackles for the ball carrier, IRR 2.59). Propensity was significantly greater for backline players than forwards (IRR 1.54, 95% CI 1.28 – 1.84), but did not increase over the course of the match. Head to head contact accounted for the most tackler HIAs, with the greatest propensity.
**Conclusions**: By virtue of its high propensity and frequency, the tackle should be the focus for interventions that may include law change and technique education. A specific investigation of the characteristics of the tackle is warranted to refine the approach to preventative strategies.

## *Introduction*

Rugby Union is a fast-paced collision sport with a high incidence of head injury and concussion[1,2]. Concussion is now the most common match injury in the professional game, accounting for 25% of all match injuries [3].

Rugby Union's governing body has been acknowledged for 'leading the way' [4] on important issues such as the formulation of an operational definition of concussion [5] and its management. However, limited progress has been made to date on the primary prevention of concussion in Rugby Union [4]. Until the game-specific risk factors for head injuries are established, appropriately targeted interventions to reduce the risk of head injury in Professional Rugby Union cannot be developed.

The all-injury propensity of various match events has been described previously in professional Rugby Union, highlighting the tackle as the most injurious event[6,7]. Two studies have conducted preliminary video analyses of tackles leading to concussion specifically, reporting that high tackles[8] in senior Rugby League and poor technique[9] in high-level schoolboy Rugby Union players are significant risk factors.

To our knowledge, no large-scale video analysis study has investigated match specific risk factors for head injuries in professional Rugby Union, though similar smaller studies exist for Rugby League[8], Australian football [10] and American football[11]. The aim of the present study, part of a series investigating the mechanisms of head injury in rugby, is to describe the match events leading to a head injury that satisfies the criteria for a Head Injury Assessment (HIA) in order to identify opportunities for primary head injury prevention that may warrant more detailed analyses in the future.

## *Methods*

This prospective cohort study was conducted between 2013 and 2015 in six major professional elite Rugby Union competitions. These were both international (Six Nations, Rugby Championship and Rugby World Cup) and national (England Premiership, Super Rugby, Top 14, Pro 12 and European Champions Cup) competitions. Ethics approval was obtained from the World Rugby Internal Ethics Committee, and all players participating in

the professional leagues provided written informed consent as part of the World Rugby Head Injury Assessment (HIA) Protocol.

All professional competitions included in this cohort agreed (as part of the competition agreement) to adopt a standardised head injury assessment and management protocol termed the Head Injury Assessment (HIA) protocol [12]. Operationally, the HIA protocol identifies eleven Criteria 1 signs and symptoms including loss of consciousness, ataxia, convulsions and tonic posturing, which require the immediate and permanent removal of the player without further assessment. If a player experiences a head impact where the diagnosis is not immediately apparent, the team doctor is allowed to access a temporary 10-minute substitution to undertake an off-field assessment using a standardized pitch-side triage tool as part of the HIA1 phase.

For this study, an HIA event was defined as any event that led to a player a) being immediately and permanently removed from play, b) receiving a pitch-side assessment resulting in removal from play or c) receiving a pitch-side assessment before returning to play. Events were captured in a central database as part of World Rugby's HIA protocol. This database was used to identify every reported HIA over the three-year study period. An estimated 112 concussions reported as delayed or evolving after the match were excluded from the present analysis as they could not be directly associated to a specific match event.

A single professional and experienced game analyst coded all HIA events using a pre-defined coding template. The coding template comprised fifteen categorical variables, describing which player sustained the head impact, the match event causing it, as well as more detailed descriptions within each match event. These detailed descriptions were based on previous studies investigating injuries in professional Rugby Union[1,7]. They included the players' speed, direction, tackle type, body positions, and whether the tackle was deemed foul play. For the present study, the variables analysed were match events, time of HIAs, the nature of head contact causing the HIA, and HIAs by playing position.

In addition, a competition representative control group of 20 matches was coded using the same pre-defined coding template as the case group by the same analyst for comparison in order to calculate HIA propensity and positional differences in match activity.

Descriptive statistics (counts, averages and proportions) were used to summarise the HIA event frequency and the average match events occurring in a match. HIA propensity is expressed as the number of HIAs per 1000 events. Incident Rate Ratios (IRRs) were calculated to compare the propensity of two events by expressing the calculated HIA propensity relative to one another. 95% confidence intervals were used based on the Poisson distribution and a difference was deemed to be significant if the 95% limits did not overlap.

## Results

### *Match event*

A total of 611 HIA events with acceptable video footage were identified in 1516 matches. 25 HIA events were excluded from analysis because video footage was insufficiently clear to identify the mechanism of head impact.

Table 1 shows the match events responsible for HIA events, including the calculated propensity of each event to cause an HIA. The period between HIA events (in matches per HIA event for each game event) is also shown as a measure of HIA event incidence.

Tackles are responsible for the most HIAs (76%), and have a significantly greater propensity (1.94 HIA events/1000 tackles) than other game events with the exception of kick contests (1.57 HIA events/1000 kick contests). As a result of having the greatest propensity and a high frequency of events per match, tackle situations result in an HIA most frequently (3.1 matches). Rucks are the second-most likely game event to result in an HIA event, with a period of 20.8 matches, before a large reduction in the period for all other game events.

Within the tackle, 335 out of 464 HIAs occur to the tackler (72%), while 129 occur to the ball carrier (28%). Tacklers experience a more than two-fold higher incident rate than ball carriers (1.40 HIAs/1000 tackles for the tackler vs 0.54 HIAs/1000 tackles for the ball carrier, IRR = 2.59, CI 2.12 – 3.18).

### *Playing position and head injury risk during tackles*

Since the tackle has the highest HIA event propensity and occurs so frequently, it was further analysed for playing position and the timing of the head impact event.

Table 2 depicts the HIA event risk during tackles for individuals of each playing position. To account for exposure to the risk event, the number of tackles made by each player within a position group is shown, along with the calculated propensity and the number of matches between HIA events to a player in each playing position.

Wings have the lowest overall risk of HIA events, with 1 HIA event occurring every 147.9 matches. The flyhalf experiences the HIA event most frequently, though differences to other positions with the exception of wings are not significant. This is the result of the interaction between propensity for head injury per tackle and that positional group's tackle frequency per match. Figure 1 shows the propensity for HIAs to occur during tackles (Fig 1A) and the relative risk of players in each playing position relative to that of the wing (Fig 1B).

Combined, backs have a significantly higher propensity for HIA events during tackles than forwards (220 HIAs, 2.62 HIAs/1000 tackles, 95% CI 2.29 to 2.98 for backs; 240 HIAs, 1.54 HIAs/1000 tackles, 95% CI 1.36 to 1.75 for forwards, IRR 1.54, 95% CI 1.28 – 1.84).

Forwards sustain a greater number of HIA events in other phases of play. A total of 147 HIA events occurred in game events other than the tackle, and of these, 88 (60%) occurred to forwards, 59 (40%) to back line players.

*Timing of HIA events during tackles*

The timing of HIA events is shown in Figure 2. There were no significant differences in the propensity of tackles to cause HIA events for the four quarters of matches.

*Nature of head contact during tackles*

Table 3 shows the HIA propensity for the tackler as a result of various types of head contact, along with the number of tackler HIA events for each contact. Data are shown for the tackler only because time constraints meant that the control cohort was analysed for the tackler only.

Propensity was greatest when the tackler's head struck the ball carrier's head (11.3 HIAs/1000 events), followed by contact with the ball carrier's elbow (IRR 1.78, CI 0.99 – 3.19, Head vs elbow), the ball carrier's knee (IRR 3.65, CI 2.22 – 6.01, Head vs knee) and the ball carrier's hip (IRR 6.57, CI 4.79 – 9.01 Head vs hip)

The lowest propensity for an HIA event occurred for contact between the tackler' head and the ball carrier's upper body (IRR 24.65, CI 17.02 - 35.71, Head vs Upper body contact).

Head-to-arm contact, head-to-ground contact, and whiplash injury were more likely to cause the HIA event in the ball carrier (Table 3). For all other head contacts, the tackler experiences the majority of HIA events, consistent with the overall relative proportion of impact events to the tackler and ball carrier.

**Discussion**

The present study is the first of a series of research studies examining the risk of significant head impacts in the sport. World Rugby's requirement to document every HIA event in the professional game has enabled us to describe 611 HIA events so that targeted prevention strategies might be developed to reduce head injuries in the sport [13,14].

Our first important finding is that the tackle exposes players to the highest risk of head injury, measured as overall proportion (76% of HIAs), propensity and incidence (Table 1). This is unsurprising given previous research documenting overall injury[6,15] and specifically concussion injury risk[1,16] during tackling.

The tackle has been characterized previously[7], with specific reference to all injury types in Rugby Union[6,17-19], revealing that high speed tackles[17,19], tackles where players are unsighted or off-balance[18], front-on tackles[7] and high collision forces[19] were more likely to cause injury.

Similar risk factors for head injuries in tackles might reasonably be expected, and understanding these may direct interventions ranging from law modifications or enforcement to technical coaching recommendations to effectively mitigate head injury risk. This is recognized as an important area of future research based on the present finding.

The second important finding is that within the tackle, it is the tackler who is at greater risk of injury (Figure 3). For every HIA event to a ball carrier, 2.6 HIA events are experienced by the tackler. This ratio differs from previous research that examined all injury types resulting from 140,269 tackles in 434 professional rugby matches, finding that the ball-carrier was 1.9 times more likely to sustain an injury than the tackler (2.9 injuries/1000 tackles to the ball carrier vs 1.5 injuries/1000 tackles to the tackler[7]).

It is however similar to a study on concussions rather than HIA events, which found a four-fold increase in risk to the tackler compared to the ball carrier[20].

This may be of significance because the current rugby laws are focused preferentially on the ball-carrier, and few laws focus on the tackler. Whether law change in this regard is possible can be explored only if the specific nature of tackler injuries is better understood.

Another area that may be considered in light of this finding is the importance of technique as a contributing factor to injury risk. Previous studies, while small in size, have found that tackles resulting in all injury and head injury had an inferior technique score than those tackles that did not result in injury[9,21]. Both studies were conducted in school-aged rugby players, and it may be argued that professional players will differ with respects to technical proficiency in tackles, but player technique represents an important avenue for further analysis and intervention.

We found that per thousand tackles, backs are significantly more likely to sustain head injuries than forwards. Indeed, there is clear separation between the backline positions and the forward positions for propensity, and no forward has a risk of HIA greater than the overall tackle risk of 1.94 HIAs/1000 tackles (Fig 1A).

The greater propensity for HIA events in backs is likely the consequence of the specific types of tackles made by backline players. In particular, the speed and direction of the tackle, which have been shown to predict injury risk [7,19], may be important risk factors.

With respects to the timing of head injuries, we find no temporal changes in HIA event propensity (Figure 2), a finding that differs compared to recently published observations of

concussion in school-aged rugby players[20,22]. McFie et al found that the incidence of concussion was significantly higher in the third and fourth quarter of matches, which might be attributed to fatigue[20], or alternatively, to an accumulated tackle load where injury risk increases with each tackle[23].

The reasons for an absence of such a pattern in our study is not immediately clear. Conditioning and skill levels of the professional players in our cohort may differ compared to youth and community players in a number of the aforementioned studies. It would be instructive to analyse whether injuries occur to substitutes or to players who have played the entire duration of the match, in order to determine whether playing time predicts risk, possibly even correcting for tackles made.

Our final finding was that the type of contact responsible for the most HIA events in tacklers is head-to- ball carrier head, followed by ball carrier hip and ball carrier shoulder (Table 3). Head-to-head contacts also had the greatest propensity for the tackler. Of interest is that all contact types with the exception of head-to-arm, head-to-ground and whiplash injuries are more likely to injure the tackler. This invites the possibility that law or technique interventions that reduce the risk of contact between the tackler's head and the head, shoulder and arm of the ball carrier might preferentially protect the tackler against head injury, and not only the ball carrier.

It is important to recognize the difference between this group of heterogeneous head injuries that required an HIA and clinically diagnosed concussion, which have been studied previously [1,2,9,20] using a descriptive epidemiological approach. The severity of the head impact event may be considered greater for concussions than for head injury events not later confirmed as concussions. This may have implications not only for understanding their occurrence, but also for interventions. For instance, McFie et al found that concussion formed a greater proportion of time-loss injuries in forwards than in backs despite a similar overall proportion of non-time loss injury[20], which may indicate that some attribute of head injuries in forwards makes them more severe than in backs. Such possibilities may be explored by comparing head injuries that are subsequently diagnosed as concussions to those that do not meet the diagnostic criteria for concussion.

In this regard, one consideration of the present study is the variability of clinical outcomes of the head injuries included in the sample. However, our objective was to describe head impact events that would lead, at a minimum, to a pitch side assessment, and at a maximum, to immediate and permanent removal confirming a concussion diagnosis. We believe this is important because the outcomes of sub-clinical head impacts have been speculated to be harmful, and because the HIA protocol represents a standardized and objective criteria for the identification of head impacts. If head impacts can be reduced through interventions, then the risk of concussion, and the number of players exposed to potentially negative long-term outcomes of head injury will also likely be reduced. Further, future analysis may compare head impacts diagnosed as concussions to those not meeting the concussion threshold, and how they may be affected differently by various game event characteristics.

Further considerations of this study include that a single professionally employed coder performed the video analysis of all 611 head impact events. We chose to do this to eliminate any inter-coder variability, and instead ensured that any ambiguous cases, where the coder was uncertain about any variable, would be discussed with another professional game analyst in order to reach consensus. The exclusion of 25 head impact events that had inadequate video footage and an estimated 112 concussions where symptoms appeared only after the match is also recognized as a limitation, since the latter in particular may differ with respects to the mechanism of injury compared to those for which video footage could be found.

Finally, with respect to the implications for management, risk reduction may focus on either the propensity of an event to cause injury, or on the exposure of players to each potentially injurious risk event. For example, kick contests have a propensity that is statistically similar to that of a tackle (1.57 HIAs/1000, 95% CI 0.93 to 2.65 vs 1.94 HIAs/1000, 95% CI 1.77 to 2.12). However, 27 tackles occur for every kick contest during match play. Given the difference in frequency, it is unsurprising that the total number of HIAs in this cohort as a result of kick contests is only 14 HIA events.

While any reduction in head injuries would be desirable, the greater impact may be made by addressing the 464 HIA events in the tackle and the 73 HIA events in rucks, even though rucks have a significantly lower propensity for head injury (0.3 HIAs/1000 rucks). This can be done either by modifying the risk within a specific event, or by shifting behaviour from more injurious events to less injurious events within tackles and rucks.

In conclusion, the tackle is highest risk match event in Rugby Union, and the tackler is exposed to the greatest risk of a significant head impact event. This invites approaches to reduce the risk of head impacts that first analyses the tackle event in greater detail in order to identify high and low risk tackle situations. After detailed analysis of the tackle has been conducted, interventions ranging from law change and reinforcement, to technique education and awareness can be considered.

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## Tables

*Table 1: Match events responsible for head injuries requiring HIAs*

| Event | HIAs | Average events per match | Propensity (95% CI), HIAs/1000 events | HIA period (95% CI), matches per HIA event |
|---|---|---|---|---|
| Tackles | 464 | 158 | 1.94 (1.77 to 2.12) | 3.1 (2.8 – 3.4) |
| Kick contests | 14 | 5.9 | 1.57 (0.93 to 2.65) | 108.3 (64.1- 182.9) |
| Mauls | 11 | 10.4 | 0.70 (0.39 to 1.26) | 137.8 (76.3 – 248.9) |
| Scrums | 9 | 16.3 | 0.36 (0.19 to 0.69) | 168.4 (87.6 – 323.7) |
| Rucks | 73 | 162.9 | 0.30 (0.24 to 0.37) | 20.8 (16.5 – 26.2) |
| Lineouts | 2 | 25.2 | 0.05 (0.01 to 0.20) | 758.0 (189.6 – 3030.9) |
| Open play | 38 | n/a | n/a | n/a |

*Table 2: Calculated HIE propensity and period by playing position (tackle only)*

| Position | HIE cases | Tackles/player/ match | Propensity (95% CI), HIAs/1000 tackles | Matches/HIE/player |
|---|---|---|---|---|
| **Backs** | | | | |
| Fly Half | 44 | 4.95 | 2.93 (2.18 to 3.94) | 68.9 (51.3 – 92.6) |
| Scrum Half | 36 | 3.80 | 3.12 (2.24 to 4.33) | 84.2 (60.7 – 116.7) |
| Centre | 68 | 5.83 | 1.93 (1.52 to 2.45) | 89.2 (70.3 – 113.1) |
| Full Back | 31 | 2.05 | 4.99 (3.51 to 7.10) | 97.8 (68.8 – 139.1) |
| Wing | 41 | 2.65 | 2.55 (1.88 to 3.46) | 147.9 (108.9 – 200.9) |
| **Forwards** | | | | |
| Hooker | 38 | 6.93 | 1.81 (1.32 to 2.49) | 79.8 (58.1 – 109.7) |
| Number 8 | 33 | 6.38 | 1.71 (1.22 to 2.41) | 91.9 (65.3 – 129.3) |
| Prop | 59 | 5.51 | 1.76 (1.36 to 2.27) | 102.8 (79.7 – 132.7) |
| Lock | 56 | 6.08 | 1.52 (1.17 to 1.98) | 108.3 (83.3 – 140.7) |
| Flanker | 54 | 7.38 | 1.21 (0.93 to 1.58) | 112.3 (86.0-146.6) |

*Table 3: HIA number, propensity and proportion to tackler as a result of various types of head contact*

| | HIAs to tackler | Propensity (95% CI), HIAs/1000 Events | % of HIAs to the tackler (95% CI) |
|---|---|---|---|
| Head - head | 84 | 11.30 (9.13 - 14.00) | 78% (69%–85%) |
| Head - elbow | 13 | 6.35 (3.69 - 10.94) | 100% |
| Head - knee | 19 | 3.09 (1.97 - 4.85) | 61% (44%–76%) |
| Head - hip | 71 | 1.72 (1.36 - 2.17) | 97% (91%–99%) |
| Head - shoulder | 46 | 1.69 (1.27 - 2.26) | 65% (54%–75%) |
| Head - arm | 20 | 1.37 (0.88 - 2.12) | 36% (25%–50%) |
| Head - lower leg | 18 | 1.36 (0.86 - 2.17) | 82% (61%–93%) |
| Head - ground | 1 | 0.73 (0.10 - 5.20) | 17% (3%–56%) |
| Head - upper body | 42 | 0.46 (0.34 - 0.62) | 79% (67%–88%) |
| Head - upper leg | 15 | 0.43 (0.26 - 0.72) | 83% (61%–94%) |
| Whiplash | 3 | - | 27% (10%–57%) |
| Head - equipment | 0 | - | |
| Head - hand (fist) | 3 | - | 75.0% (30%–95%) |